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## 1 Atomic and Nuclear Structure

This is a new, contributed topic intended to cover the essential aspects of the broad theme of both atomic and nuclear structure. Applications, such as Nuclear Engineering, may be covered only partially here, and there should be a separate new topic on Nuclear Engineering, nuclear fission reactors, nuclear fusion reactors, tokamaks, and similar subjects.

Any member of PlanetPhysics.org can contribute to adding and editing this entry.

The following four subsections introduce elementary [concepts](#) that are being cited here only in part from reference 1.

### 1.1 Basic Concepts of Atomic and Nuclear Structure

- “The *atom* consists of two components - a nucleus (positively charged) and an electron cloud (negatively charged); the *radius of the nucleus* approximated by a sphere is about 10,000 times smaller than that of the atom;
- The *Nucleus of an Atom* or *Atomic Nucleus* can have two component particles - [neutrons](#) (no [charge](#)) and protons (positively charged) - collectively called [nucleons](#);
- The [mass](#) of a proton is about equal to that of a neutron - and is about 1,840 times that of an electron;
- The number of protons equals the number of electrons in an isolated atom;”
- The *Atomic Number* specifies the number of protons in a nucleus;
- The *Mass Number* specifies the number of nucleons in a nucleus;
- *Isotopes* of elements are atoms with the same atomic number but different mass numbers; “Isotopes are classified by specifying the element’s chemical symbol preceded by a superscript giving the mass number and a subscript giving the atomic number;
- The atomic mass unit is defined as 1/12th the mass of the stable, most commonly occurring isotope of carbon (i.e. C-12);”
- The *Nuclear Binding Eenergy* is the energy which holds the nucleons together in a nucleus and is measured in electron volts (eV);
- The number of neutrons increases more rapidly in the *Periodic Table* than the number of protons, thus giving rise to the Nuclear Stability Curve; “there are about 2450 isotopes of about 100 elements and the unstable isotopes lie above or below the Nuclear Stability Curve; there are about 2450 isotopes of some 100 elements, and the unstable isotopes lie above or below the Nuclear Stability Curve; the *Nuclear Stability Curve* is a 2D [graph](#) or plot of the stability of various ‘natural’ nuclei against the atomic

number;” Unstable isotopes ‘attempt’ to reach the nuclear stability curve by splitting into fragments (fission) or by emitting particles/energy (radioactivity);

- *Unstable isotopes* are isotopes that are radioactive isotopes and are also called *radionuclides*; “about 300 of 2450 isotopes are found in nature - the rest are produced artificially in *nuclear reactors*”.

## 1.2 Radioactivity and Radioactive Decay

## 1.3 Nuclear Fission processes and Reactors

## 1.4 Nuclear Fusion Experiments and Installations

## 1.5 Units of Radiation Measurement

- *Radiation Exposure* expresses the intensity of an X- or gamma- ray beam;
- *Radiation Adsorbed Dose* expresses the accumulated, absorbed amount of radiation;
- The *SI unit of radiation exposure* is the coulomb per kilogram (C/kg); 1 C/kg = The quantity of X- or gamma-rays such that the associated electrons emitted per kg of air at STP produce in air ions carrying 1 coulomb of electric charge;
- The traditional unit of exposure is the roentgen (R);  $1R = \text{The quantity of X- or gamma-rays such that the associated electrons emitted per kg of air at STP produce in air ions carrying } 2.58 \times 10^{-4} \text{ coulombs of electric charge;}$
- The exposure rate is the exposure per unit time, e.g. C/kg/s;
- Absorbed dose is the radiation energy absorbed per unit mass of absorbing material; The SI unit of absorbed dose is the gray (Gy);  $1Gy = \text{The absorption of 1 joule of radiation energy per kilogram of material;}$  The traditional unit of absorbed dose is the rad;  $1rad = \text{The absorption of } 10^{-2} \text{ joules of radiation energy per kilogram of material;}$

## 1.6 Interaction of Radiation with Matter

- “Alpha-Particles: exert considerable electrostatic attraction on the outer orbital electrons of atoms near which they pass and cause ionisations; travel in straight lines - except for rare direct [collisions](#) with nuclei of atoms in their path; their energy is always discrete.
- Beta-Minus Particles: attracted by nuclei and repelled by electron clouds as they pass through matter and cause ionisations; have a tortuous path; have a range of energies; this range of energies results because two particles are emitted - a beta-particle and a [Neutrino](#).

image processing; A collimator is used to improve the spatial resolution of a gamma-camera; Collimators typically consist of a *Pb* plate containing a large number of small holes; The most common [type](#) is a parallel multi-hole collimator; The most resolvable area is directly in front of a collimator; Parallel-hole collimators vary in terms of the number of holes, the hole diameter, the length of each hole and the septum thickness – the combination of which affect the sensitivity and spatial resolution of the imaging [system](#); Other types include the diverging-hole collimator (which generates minified images), the converging-hole collimator (which generates magnified images) and the pin-hole collimator (which generates magnified inverted images); Conventional imaging with a gamma camera is referred to as Planar Imaging, i.e. a 2D image portraying a 3D [object](#) giving superimposed details and no depth information;

- *Single Photon Emission Computed Tomography (SPECT)* produces images of slices through the body; SPECT uses a gamma camera to record images at a series of angles around the patient; The resultant data can be processed using Filtered Back Projection and Iterative Reconstruction; SPECT gamma-cameras can have one, two or three camera heads;
- *Positron Emission Tomography (PET)* also produces images of slices through the body; PET exploits the positron annihilation process where two 0.51 MeV back-to-back gamma-rays are produced; If these gamma-rays are detected, their origin will lie on a line joining two of the detectors of the ring of detectors which encircles the patient;
- **PET systems require an on-site, or nearby, cyclotron to produce short-lived radioisotopes, such as  $C - 11$ ,  $N - 13$ ,  $O - 15$  and  $F - 18$ .**

more to come...

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Keywords: atom, nucleus, nucleon, particles, electron, proton, neutron, radioactivity, nuclear physics, atomic physics, nuclear fusion reactor, tokamak, radioactivity, nuclides, radiopharmaceuticals, atomic mass, atomic number, periodic table, nuclear structure in astrophysics, nuclear engineering, nuclear reactions, proton, neutron, nucleon, quarks, nucleon structure, radiation, Compton effect, photoelectric effect, alpha particle, beta particle, Gamma radiation

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